

<p align="center"><b>LLNL Environmental Restoration Division Standard Operating Procedure</b></p>	<p align="center"><b>TITLE: Presample Purging of Wells</b></p>
<p><b>APPROVAL</b> _____ <b>Date</b> _____</p> <p><b>Environmental Chemistry and Biology Group Leader</b></p>	<p align="center"><b>PREPARERS: P. Daley, R. Goodrich, and G. Howard</b></p> <p align="center"><b>REVIEWERS: R. Brown*, E. Christofferson*, V. Dibley, J. Duarte, B. Failor*, J. Greci, B. Hoppe*, and B. Ward*</b></p>
<p><b>APPROVAL</b> _____ <b>Date</b> _____</p> <p><b>Division Leader</b></p> <p><b>CONCURRENCE</b> _____ <b>Date</b> _____</p> <p><b>QA Implementation Coordinator</b></p>	<p align="center"><b>PROCEDURE NUMBER: ERD SOP-2.1</b></p> <p align="center"><b>REVISION: 2</b></p> <p align="center"><b>EFFECTIVE DATE: December 1, 1995</b></p> <p align="center"><b>Page 1 of 18</b></p>

\*Operations and Regulatory Affairs Division

## 1.0 PURPOSE

The purpose of this procedure is to identify well purging (evacuation) procedures that will ensure enough stagnant water in the well is replaced by ground water so a representative sample of the aquifer can be collected.

## 2.0 APPLICABILITY

This procedure provides guidelines for field personnel to purge wells adequately and appropriately by using sampling devices, such as a bailer, bladder pump, or an electric submersible pump prior to sample collection.

## 3.0 REFERENCES

- 3.1 Barcelona, M. J., J. P. Gibb, J. A. Helfrich, and E. E. Garske (1985), *Practical Guide to Ground Water Sampling*, U.S. Government Printing Office, Washington, D.C. (EPA/600/2-85/104).
- 3.2 Korte, N. and P. Kearl (1984), *Procedures For The Collection and Preservation of Ground Water and Surface Water Samples and for the Installation of Monitoring Wells*, U.S. Department of Energy, Grand Junction, Colo.

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- 3.3 Morrison, R. D. (1983), *Ground Water Monitoring Technology, Procedures, Equipment and Applications*, TIMCO Manufacturing, Inc., 85-90.
- 3.4 U.S. EPA (1992), *RCRA Ground-Water Monitoring: Draft Technical Guidance*, Washington, D.C. (EPA/530-R-93-001).

## **4.0 DEFINITIONS**

### **4.1 Bailer**

A bailer is recommended for evacuating shallow, small-diameter wells or larger diameter wells with low yields and/or small casing volumes. A bailer is a small-diameter cylindrical shaped tube made from Teflon, stainless steel, polyvinyl chloride (PVC) or polyethylene materials. A check ball is housed in the bottom of the tube. The check ball rises as the tube is lowered downhole allowing the tube to fill with water. As the tube is raised to the surface the check ball seats, preventing water loss. To collect a sample from the tube, a bottom-emptying device is inserted into the tube which expels the water. Appropriate sample containers are then filled.

### **4.2 Bladder Pump**

Bladder pumps are used to evacuate low-yielding wells, which produce <1.0 gpm. A bladder pump, such as a Well Wizard is an enclosed cylindrical plastic or stainless steel tube containing a Teflon membrane bladder. Well water enters the bladder through a one-way check valve at the bottom. Compressed gas as is forced into the annular space between the tube causing the bladder, compressing the bladder, thus forcing the water up the discharge line and to the surface.

### **4.3 Electric Submersible Pump**

The submersible pump is commonly used for purging high-volume, large-diameter wells that require high pumping rates. An electric submersible pump is a motor driven device that forces water to the surface through centrifugal action. This action is accomplished by impellers housed in a stainless steel cylindrical casing that propels water up the discharge pipe and to the surface. Some electric submersible pumps are controlled by a rheostat mechanism allowing better control and much lower discharge rates to be achieved.

## **5.0 RESPONSIBILITIES**

### **5.1 Division Leader**

The Division Leader's responsibility is to ensure that all activities performed by ERD at the Livermore Site and Site 300 are performed safely and comply with all pertinent regulations and procedures, and provide the necessary equipment and resources to accomplish the tasks described in this procedure.

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## **5.2 Field Personnel**

The field personnel are responsible for the safe completion of evacuating and containing purge water from monitor wells according to guidelines set forth by this procedure, as well as other associated SOPs. The wells to be purged on a frequent basis are declared in the quarterly Routine Sampling Schedule provided by the Sampling Coordinator.

## **5.3 Field Support Personnel**

The field support personnel are responsible for providing necessary equipment, collection devices, and general field support, which enables sampling personnel to perform field activities in a timely and efficient manner.

## **5.4 Sampling Coordinator (SC)**

The SC's responsibility is to supply a quarterly Routine Ground Water Sampling Schedule. In addition to providing an overall sampling plan, the SC has the option to provide a specific sample plan for each day (Daily Operations Guide). The technical information required for purging wells is also provided by the SC in the Well Specification Table.

# **6.0 PROCEDURE**

## **6.1 Procedure Exception**

Tritium is considered a conservative contaminant (i.e., it will not volatilize [fractionate] or change activity appreciably upon contact with the atmosphere) therefore, presample purging is not necessary. SOP 2.9, "Sampling for Tritium in Ground Water," discusses tritium sampling in more detail. Also, presample purging of low-yielding monitor wells is covered under SOP 2.7, "Presample Purging and Sampling of Low-Yielding Monitor Wells."

## **6.2 Dedicated Sampling Devices**

- 6.2.1 In most cases, monitor wells that are infrequently sampled, purged and sampled with a bailer, produce too little water or are newly drilled, will not have dedicated sampling devices. If the well is not fitted with a dedicated sampling device, the procedure and/or temporary equipment required for well evacuation is determined by the SC.
- 6.2.2 Frequently sampled monitor wells have dedicated sampling pumps and associated equipment necessary to purge and sample the well. Discharge and sampling tubes are dedicated and are stored inside the steel protective casing. In most cases, control boxes for electric submersible pumps up to 1.5 hp are also dedicated and are locked inside the protective casing. Portable control boxes are normally used on pumps greater than 1.5 hp. Installation of dedicated pumps is described in SOP 2.8, "Installation of Dedicated Sampling Pumps."

## **6.3 Office Preparation**

- 6.3.1 Prior to commencement of field activities, all SOPs, OSPs, and Site Safety Plans applicable to successfully performing a task should be reviewed by field

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personnel. Current copies of all relevant documents shall be retained in the sampling vehicle at all times.

6.3.2 Review all pertinent sampling information, such as the quarterly Routine Sampling Schedule and Well Specification Table provided by the SC. The schedule contains the following information:

- Well to be sampled.
- Requested analyses.
- Contract analytical laboratory to which samples are to be sent to for analyses.
- Estimated amount of purge water to be collected, and where and how it will be treated.

6.3.3 Obtain appropriate data collection forms (i.e., Ground Water Sampling Logs [Attachment A] and assigned field logbook).

6.3.4 Consult with the SC for the appropriate presample purging method to apply to the site.

## **6.4 Field Preparation**

6.4.1 Purge Water Collection

A. Site 300

After consulting with the SC, the field support personnel must ensure that wells have sufficient collection drums available at the well head for purge water containment (SOP 4.7B, "Site 300 Treatment and Disposal of Well Development and Well Purge Fluids"). The quantity of purge water to be collected for each well is listed in the Routine Sampling Schedule.

B. Livermore Site

The SC will provide a specific order of wells to be sampled, in order to efficiently coordinate placement of presample purge water collection tankers. Tankers and drums containing purge water may not be left at the well location and will be logged and disposed of according to SOP 4.7A, "Livermore Site Treatment and Disposal of Well Development and Well Purge Fluids."

6.4.2 The quarterly Routine Sampling Schedule contains contaminant information and should be consulted prior to using a bailer to determine the proper protective equipment to use. The SC will provide contaminant information for newly drilled installations that may not appear on the schedule.

6.4.3 Obtain appropriate materials to conduct field work according to Attachment B, Equipment Checklist.

## **6.5 Operation**

6.5.1 A well entry logbook is kept in each well and locked inside the well casing. Whenever a well is entered for any reason, record the date, the purpose, name of the operator, and any water level obtained in the logbook. Replace the logbook in the well when operations are complete.

6.5.2 Calculate and record the amount of water in the well (casing volume) as described in steps A through E:

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- A. Record the well ID, date, and chain-of-custody document number on the appropriate Ground Water Sampling Log (Attachment A).
- B. Unlock the steel protective casing and obtain depth to water (in feet) in the well. Record this information on the appropriate Ground Water Sampling Log (Attachment A) and the well entry logbook as discussed previously.
- C. Subtract the depth to water from the depth of casing (in feet). Refer to the Well Specification Table for the depth of casing. Make sure both measurements are referenced to the same point of measurement (POM). Record this result as water in casing (feet) on the Ground Water Sampling Log (Attachment A).
- D. The casing diameter for each well can be found in the Well Specification Table. The casing diameter should be recorded on the Ground Water Sampling Log. Multiply the water in casing by the volume factor appropriate for the casing diameter:

<b>Casing diameter</b>	<b>Volume factor</b>
<b>2 in.</b>	<b>0.163</b>
<b>3 in.</b>	<b>0.37</b>
<b>3.5 in.</b>	<b>0.50</b>
<b>4 in.</b>	<b>0.65</b>
<b>4.25 in.</b>	<b>0.74</b>
<b>4.5 in.</b>	<b>0.83</b>
<b>6 in.</b>	<b>1.47</b>
<b>8 in.</b>	<b>2.61</b>
<b>10 in.</b>	<b>4.08</b>

- E. The result represents the amount of water in a single casing volume and should be recorded as Gallons/Casing Vol. on the LLNL Ground Water Sampling Log (Attachment A).

### 6.5.3 Bailer Operation

It is preferable to use a Teflon or stainless steel bailer. However, polyvinyl chloride (PVC) bailers are acceptable for well purging, although they should not be used to sample wells. Attachment C is a schematic of a typical bailer. Collection of an equipment blank sample may be necessary when using a portable purging device, consult SOP 4.9, "Collection of Field QC Samples" for this determination.

- A. The retrieval line should be securely attached to the bailer. For nylon or cotton ropes, this is done by tying a bowline knot. If nylon rope is used, it should be new, unused or has been dedicated to the monitor well to be evacuated. The rope should be cut to the appropriate length according to the casing depth of the well. Bailers should be checked for cracks and breaks that could cause water and/or bailers loss, or operator contamination.
- B. Lower the bailer gently into the well and begin water removal. Avoid unnecessary agitation of the water. Collect or dispose of purged water in

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acceptable containers as specified in SOP 4.7A, "Livermore Site Treatment and Disposal of Well Development and Well Purge Fluids," or SOP 4.7B, "Site 300 Treatment and Disposal of Well Development and Well Purge Fluids."

- C. Field measurements of pH, specific conductance, and temperature should be taken at least once per casing volume purged, as described in SOP 2.2, "Field Measurements on Surface and Ground Waters." Depth to water and visual observations, such as clarity and outgassing should also be made and recorded at each volume interval. If it is suspected that the well may go dry prior to the removal of three casing volumes, at least two sets of field measurements should be taken during the removal of the first casing volume.
- D. Purge a minimum of three casing volumes, or until the pH, temperature, and specific conductance of the discharge water stabilize, whichever occurs last. Stabilization is reached when no upward or downward trends are apparent, pH is within 0.1 pH unit, temperature is within 0.5°C, and specific conductance is within 50 µmhos/cm. When sampling wells under RCRA (Resource Conservation and Recovery Act) guidelines, an additional set of field measurements should be taken at 2-minute to 3-minute intervals at the end of the third well casing volume and prior to sample collection as described in SOP 2.7.
- E. If the well does not produce three casing volumes of water, SOP 2.7 should be consulted.

#### 6.5.4 Bladder Pump (Gas-Operated Squeeze Pump) Operation

- A. On the sanitary seal of the wellhead, two quick-connect fittings should be visible. The discharge/sampling tube is suspended from the sanitary seal down into the well casing. See Attachment D for wellhead completion details.
- B. Start up the gas-powered compressor controller assembly. Attach the compressor to the gas quick-connect, ensuring the exhaust is downwind from the well. Remove the discharge/sampling tube and attach to the discharge quick-connect. Adjust bladder pump controller per equipment operation manual.
- C. Begin water removal. If possible, the rate should be set so the screen section of the casing is not exposed to air. Collect or dispose of purged water in acceptable containers as specified in SOP 4.7A or 4.7B.
- D. Measure the rate of discharge (Q) frequently by first determining the length of time in one cycle. The cycle begins when water first appears at the discharge tube, and ends when it appears at the tube a second time. Then, using a graduated cylinder for measurement, note the amount of water collected (usually less than 500 ml/cycle). Divide 60 seconds by the cycle time. Take this figure and multiply it by the mls collected. Multiply this figure by the conversion factor .264 Example: Cycle time = 17 sec. and ml per cycle = 500 ml.;  $60 \text{ divided by } 17 = 3.5 \times .500 = 1.76 \times .264 = .465 \text{ gpm}$ .
- E. Take field measurements of pH, specific conductance, and temperature at least once per casing volume purged, as described in SOP 2.2, "Field Measurements on Surface and Ground Waters." Also, measure and record depth to water, flow rate (Q), and visual observations such as outgassing. If

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it is suspected that water discharge will cease, due to well going dry and prior to removing three casing volumes, at least two sets of field measurements should be taken during the removal of the first casing volume.

- F. Purge a minimum of three casing volumes, or until the pH, temperature, and specific conductance of the discharge have all stabilized, whichever occurs last. Stabilization is reached when no upward or downward trends are apparent, pH is within 0.1 pH unit, temperature is within 0.5°C, and specific conductance is within 50 µmhos/cm. When sampling wells governed by RCRA follow procedures outlined above in Section 6.5.3 D.
- G. If water discharge ceases prior to the removal of three casing volumes, SOP 2.7, should be consulted.

#### 6.5.5 Electric Submersible Pump Operation

The dedicated pump assembly and sealed electric drive motor are submersed in the well. The pump is suspended by the discharge tubing, safety cable, and electric lead wires which are held in place by the sanitary seal. A portable generator provides power for the pump. On the sanitary seal of the wellhead, a capped discharge pipe and a capped sounding tube should be visible. The electrical cable to the pump is also fitted through the sanitary seal. The cable either has a dedicated control box or is completed with an outlet for a portable control box. See Attachment E for wellhead completion details.

- A. Place the generator downwind from the well. If the well is expected to dry out, a pump protector, such as a Coyote, can be used. This will automatically shut down the pump if the well is in danger of drying out. If a pump protector is not used, water levels should be monitored frequently to ensure the water level does not drop below the pump intake.
- B. Attach the dedicated sample tee (found inside the protective steel casing) to the discharge pipe. Plug the control box into the generator and start generator. Adjust the discharge rate so that the well will yield water without exposing the screen by partially closing the ball valve on the sample tee. If using a rheostat equipped pump, the discharge rate is controlled by the pump speed control knob on the controller unit. Purge the well as described above (Section 6.5.4 C, E, F, and G.)

#### 6.5.6 Portable Pump Assemblies

Both bladder and electric submersible pumps are available as portable units. The portable bladder pump assemblies consist of the pump, gas tube, discharge tubes lined with Teflon, and a controller. The electric submersible pump assemblies consist of the pump, a discharge tube, control box, electrical lead wires, and safety cable. The pump is generally on a spool, which can be used to lower the pump assembly into the well. If necessary, a pump installation truck can be used to secure the pump in place. Portable pumps should be thoroughly decontaminated prior to use according to SOP 4.5, "General Equipment Decontamination." Collection of an equipment blank sample may be necessary when using a portable purging device, consult SOP 4.9, "Collection of Field QC Samples" for this determination.

- A. Slowly lower the pump assembly down until the pump is at the middle of the screened interval. On low-yielding aquifers, the pump should be placed just

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above the bottom of the well so that it can be completely evacuated. Refer to the Well Specification Table to find the screened interval of the well or check with the SC on placement of the pump intake. In some cases, it may be preferable to set the pump intake at the top of the water column, and then move the pump assembly down as water is removed from the well until the top of the screened interval is reached.

- B. For bladder pumps, attach the gas tube to the gas-powered controller compressor unit. Ensure that the unit is downwind from the well.
- C. For electric submersible pumps, plug the control box to the appropriately rated generator. Ensure that the generator is downwind from the well.
- D. Purge the well and collect the purge water as described above under Section 6.5.4 C, E, F, and G.

## **6.6 Post Field Operation**

- 6.6.1 Continue water sampling as noted in all water sampling sections. See SOPs 2.2 through 2.10.
- 6.6.2 When sampling is complete, properly store all dedicated equipment. Decontaminate all nondedicated equipment per SOP 4.5, "General Equipment Decontamination."

## **6.7 Office Post Operation**

- 6.7.1 See SOP 4.1, "General Instructions for Field Personnel."
- 6.7.2 Make copies of logbook pages and Ground Water Sampling Logs. Hand carry or fax copies to the SC daily.
- 6.7.3 The SC will retain a copy of the ground water sampling to the Data Management Group (DMG) for archive. The DMG will provide copies to the appropriate Operations and Regulatory Affairs Division Analyst, as necessary.

## **7.0 QA RECORDS**

- 7.1 LLNL Ground Water Sampling Log
- 7.2 Logbooks

## **8.0 ATTACHMENTS**

- Attachment A—LLNL Ground Water Sampling Log
- Attachment B—Equipment Checklist
- Attachment C—Schematic of a Typical Bailer and Stop-Cock
- Attachment D—Wellhead Completion and Pump Placement for Bladder Pumps
- Attachment E—Wellhead Completion and Pump Placement for Electric Submersible Pumps

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## **Attachment A**

### **LLNL Ground Water Sampling Log**

# LLNL GROUND WATER SAMPLING DATA

Well Id: \_\_\_\_\_

Date: \_\_\_\_\_ Log#: \_\_\_\_\_ C of C Doc. #: \_\_\_\_\_

Purging Method: \_\_\_\_\_ Clean well: y / n Contaminant present: \_\_\_\_\_

\*ES / RF / BP / TB / PB / OTHER (circle one) Dry Out: y / n Recharge Time: \_\_\_\_\_  
Dedicated / Portable

Depth of Casing: \_\_\_\_\_ Casing Diameter: \_\_\_\_\_

Depth to Water: \_\_\_\_\_ Volume Factor: \_\_\_\_\_

Water in Casing (ft): \_\_\_\_\_ Casing Vol (gal/time): \_\_\_\_\_

Time Pump On: \_\_\_\_\_ Initial Flow Rate (Q=gpm): \_\_\_\_\_

Time Pump Off: \_\_\_\_\_ Measured by: grad. cylinder / bucket / flow meter / other

Time	Q	Gal. Purged	Well Volumes	pH	Temp C	SC	mV	OG	DTW

Meter Serial # Calibrated

pH \_\_\_\_\_ yes/no

S.C. \_\_\_\_\_ yes/no

mV \_\_\_\_\_ yes/no

H2O \_\_\_\_\_ yes/no

H2O \_\_\_\_\_ yes/no

Project: \_\_\_\_\_

Sampler's Release # \_\_\_\_\_

Analytical Lab(s) \_\_\_\_\_

Samplers Initials/Employer: \_\_\_\_\_

Sample ID.: (verify) \_\_\_\_\_ QC Sample ID: \_\_\_\_\_

Time Collected: \_\_\_\_\_

Requested Analyses / Sample Container (Size/Preserv.)/ Specific Compounds (circle below all desired)

- |  |  |  |
|--|--|--|
| <input type="radio"/> EPA601 / __3__x40 ML VOAs / 0 pres.  | <input type="radio"/> General Mineral / 2x1L plastic     | <input type="radio"/> Ra 226,228 / 2x1L plastic    |
| <input type="radio"/> EPA624 / __3__x40 ML VOAs / 0 pres.  | <input type="radio"/> Metals / 1x1L plastic              | <input type="radio"/> Th 228, 232 / 1x1L plastic   |
| <input type="radio"/> EPA625 / 3x1L amber glass            | <input type="radio"/> Cr+6 / 1x500ml plastic / 0 pres.   | <input type="radio"/> Tritium / 2x40ml VOA         |
| <input type="radio"/> EPA502.2 / 5x40 mL VOAs/0 pres.      | <input type="radio"/> Cyanide by EPA335.2 / 1x1L plastic | <input type="radio"/> Tritium / 1x250ml plastic    |
| <input type="radio"/> DWP by EPA608/615 / 6x1L amber glass | <input type="radio"/> Alpha/Beta / 1x1L plastic          | <input type="radio"/> Tritium / 1x500 ml glass     |
| <input type="radio"/> TPH Diesel/3x1L amber glass          | <input type="radio"/> Pu / 1x1L plastic                  | <input type="radio"/> U 234,235,238 / 1x1L plastic |
| <input type="radio"/> HE/1x1L amber glass/HMX,RDX,TNT      | <input type="radio"/> TOC / 3x40ml VOAs                  | <input type="radio"/> TBOS / 1X1L amber glass      |
| (total of 3x1L amber glass QC, 1 well/day)                 | (total of 9 VOAs for QC, 1 well/day)                     | (3x1L amber glass for QC, 1 well/day)              |
| <input type="radio"/> _____                                | <input type="radio"/> Phenolics / 1x1L glass             | <input type="radio"/> TOX / 1x1L amber glass       |

COMMENTS :

\*ES=ELECTRICAL SUBMERSIBLE, RF=REDIFLO, BP=BLADDER PUMP, TB=TEFLON BAILER, PB=POLYETHYLENE BAILER

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## **Attachment B**

### **Equipment Checklist**

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## Equipment Checklist

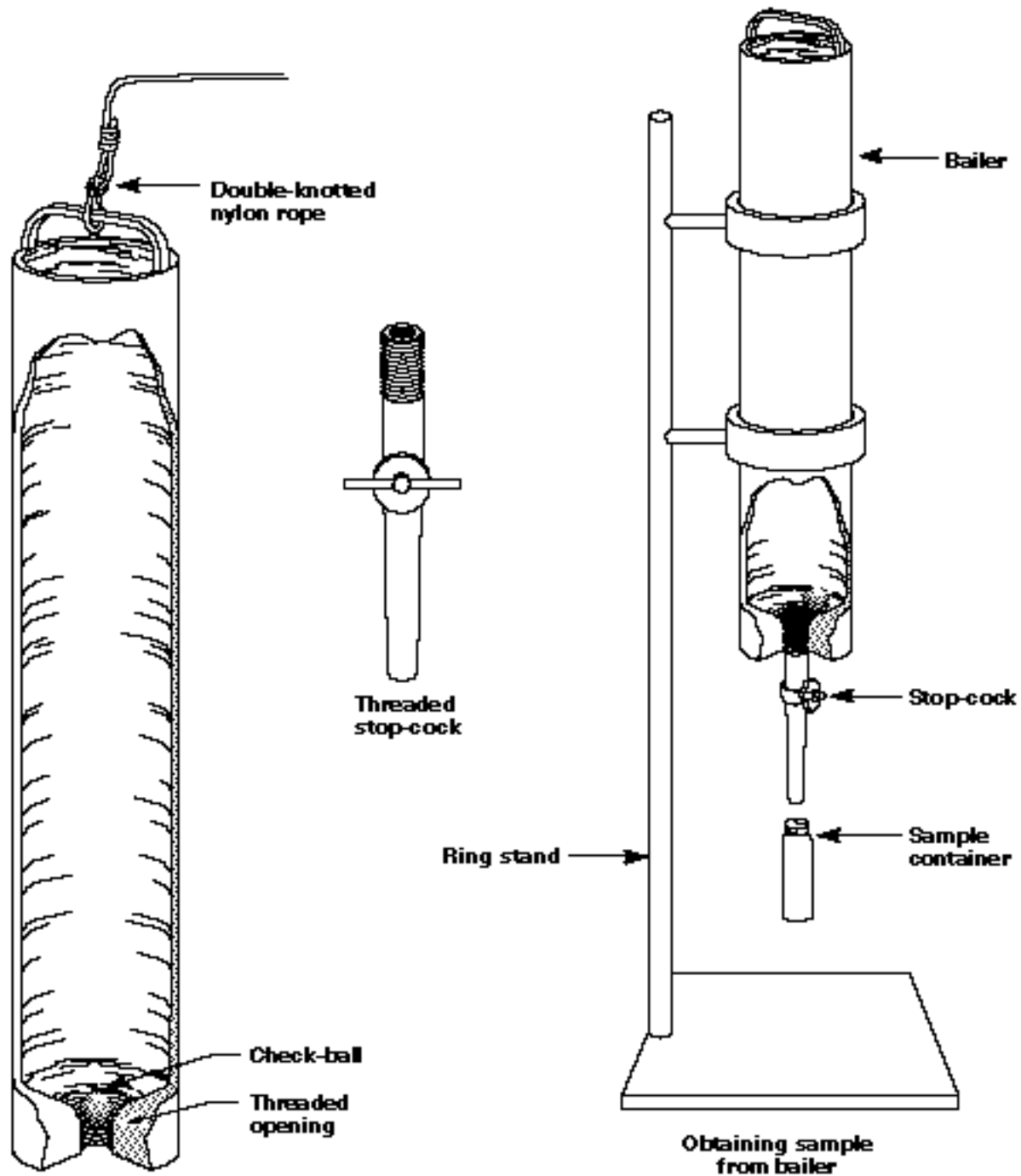
The purpose of the list presented below is to aid field personnel in identifying those supplies necessary to conduct a particular field operation. It is not intended to be all inclusive. It is the responsibility of field personnel to determine and obtain the supplies required for successful performance of assigned tasks.

- \_\_\_\_\_ Alconox (detergent)
- \_\_\_\_\_ All applicable documents (i.e., Sampling Plan, Well Specification Table, SOPs, QAPP, Site Safety Plan (SSP), Site maps, etc.)
- \_\_\_\_\_ Air tight plastic bags
- \_\_\_\_\_ Appropriate sample containers and sample preservative
- \_\_\_\_\_ Appropriate shipping documents
- \_\_\_\_\_ Bagged cubed or blue ice
- \_\_\_\_\_ Bailer and cotton or nylon bailing rope
- \_\_\_\_\_ Barricades/traffic cones
- \_\_\_\_\_ Beakers
- \_\_\_\_\_ Bound logbook
- \_\_\_\_\_ Bubble wrap or necessary packaging
- \_\_\_\_\_ Calculator
- \_\_\_\_\_ Chain-of-Custody (CoC) forms
- \_\_\_\_\_ Clipboard
- \_\_\_\_\_ Cold weather gear/rain suit (if necessary)
- \_\_\_\_\_ Coolers
- \_\_\_\_\_ Distilled (organic-free) water
- \_\_\_\_\_ Drinking water
- \_\_\_\_\_ Duct tape
- \_\_\_\_\_ Ear plugs
- \_\_\_\_\_ Field forms
- \_\_\_\_\_ First aid kit
- \_\_\_\_\_ Fittings (i.e., quick disconnect fittings for well wizards)
- \_\_\_\_\_ Generator
- \_\_\_\_\_ Graduated cylinder/bucket
- \_\_\_\_\_ Hat and work gloves
- \_\_\_\_\_ Organic Vapor Analyzer (OVA) and/or photoionization detector (PID)
- \_\_\_\_\_ Pens, pencils, permanent markers
- \_\_\_\_\_ pH, SC, temperature meters and flow cell (ASTM approved)
- \_\_\_\_\_ Personal protective equipment
- \_\_\_\_\_ Preprinted labels
- \_\_\_\_\_ Radio (when appropriate)
- \_\_\_\_\_ Safety shoes/boots
- \_\_\_\_\_ Sample-tee
- \_\_\_\_\_ Snake guards
- \_\_\_\_\_ Stop watch
- \_\_\_\_\_ Sun screen
- \_\_\_\_\_ Tape measure (tenths)
- \_\_\_\_\_ Teflon tape
- \_\_\_\_\_ Tool box
- \_\_\_\_\_ Trip blanks/field blanks
- \_\_\_\_\_ Volume conversion chart
- \_\_\_\_\_ Water level indicator

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## **Attachment C**

### **Schematic of a Typical Bailer and Stop-Cock**



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## **Attachment D**

### **Wellhead Completion and Pump Placement for Bladder Pumps**

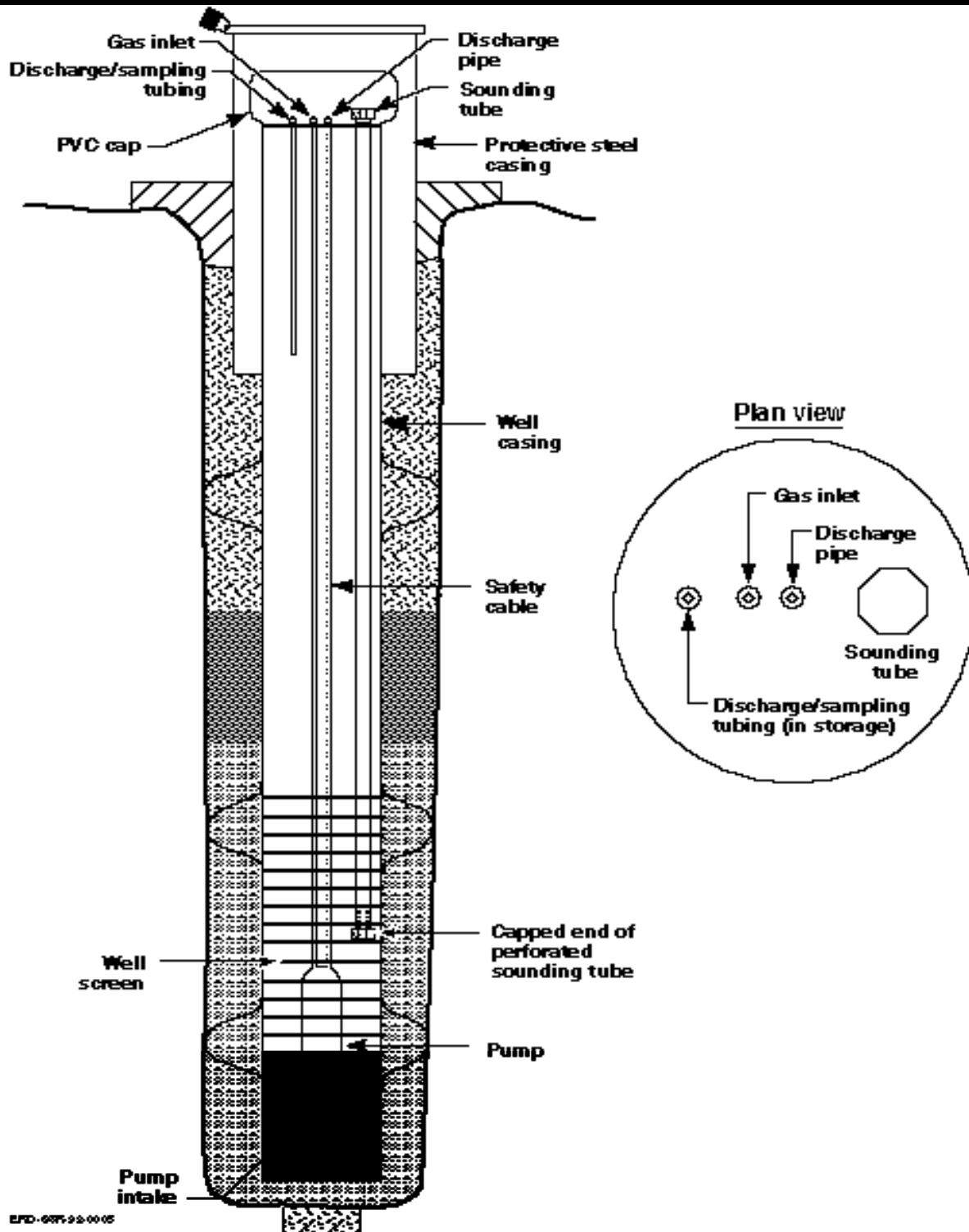
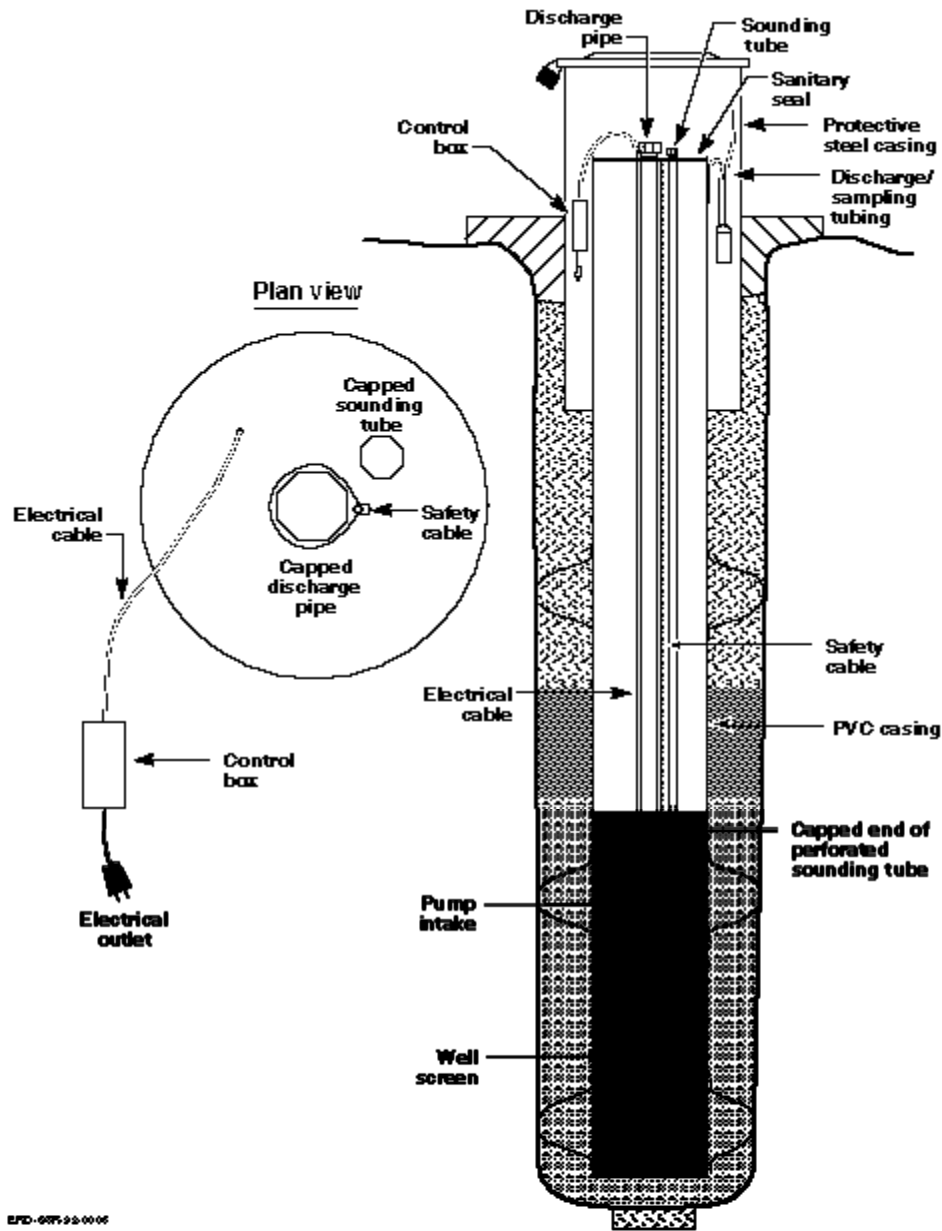


Figure 2.1-2. Wellhead Completion and Pump Placement for Bladder Pumps.

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## **Attachment E**

### **Wellhead Completion and Pump Placement for Electric Submersible Pumps**



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Figure 2.1-3. Wellhead Completion and Pump Placement for Electric Submersible Pumps.